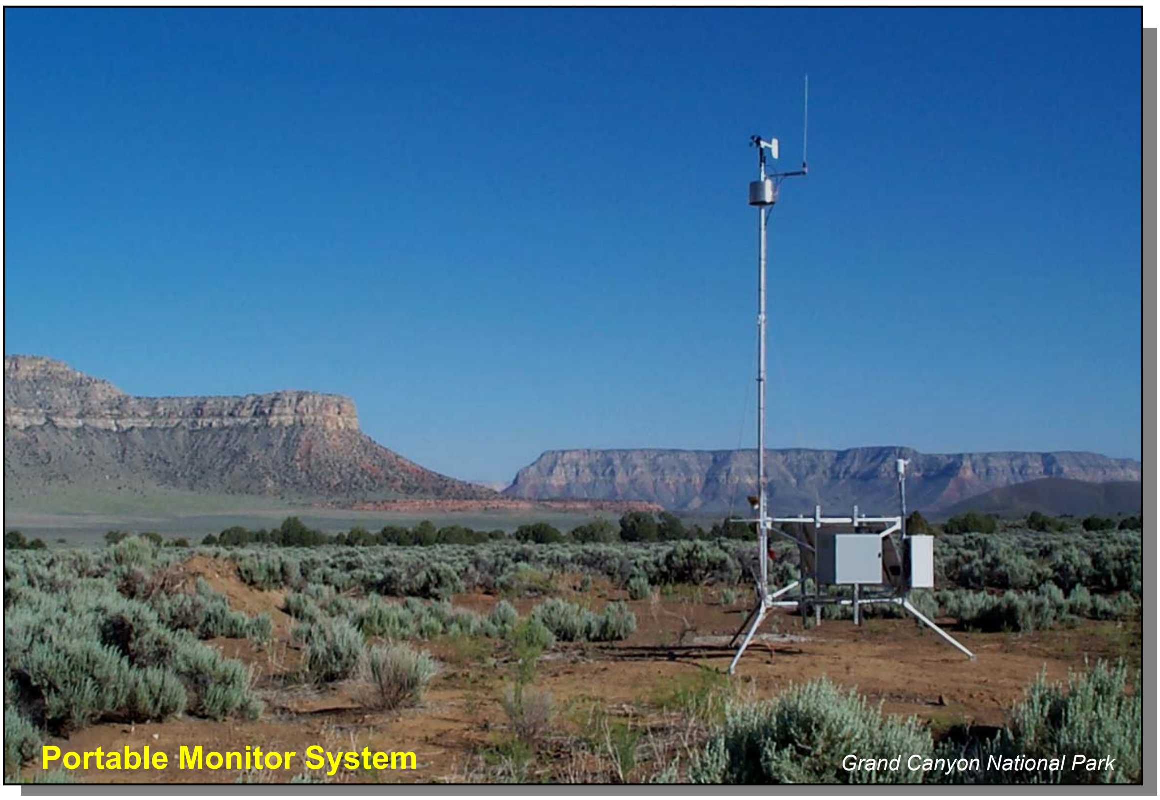
National Park Service
U.S. Department of the Interior

Air Resources Division

Ozone Monitoring Protocol

Guidance on Selecting and Conducting Ozone Monitoring



Air Resources Division
Research and Monitoring Branch
Lakewood, CO

June, 2004

FOREWORD

This document is intended to provide guidance to natural resource managers who are considering including ozone monitoring in their Vital Signs monitoring strategy. The information will help managers decide if ozone monitoring would help a park or network meet resource management objectives, and presents optional, appropriate monitoring methods. The types of data provided by each method and requirements for monitor siting, operation, data handling, and costs are discussed. Parks and networks are strongly urged to contact the National Park Service, Air Resources Division for additional guidance on ozone monitoring.

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1.0 OVERVIEW

1.1 BACKGROUND

Air pollution associated with this country's increased industrialization and urbanization over the last several decades is adversely affecting sensitive natural and cultural resources at many National Park Service (NPS) areas. Human-caused air pollutants can injure various species of plants, acidify water bodies, reduce visibility, leach nutrients from soils, and erode buildings and monuments. Air pollution may also cause or aggravate respiratory symptoms in visitors and employees of our national parks.

The NPS, as a function of its founding legislation (Organic Act of 1916), is responsible for the protection and conservation of the areas it manages in order to "leave them unimpaired for the enjoyment of future generations." NPS also has an affirmative responsibility under the Clean Air Act to protect parks and their resources from new sources of air pollution and to participate in national and regional initiatives to control air pollution. Protecting air quality in our national parks requires extensive knowledge about the origin, transport, and transformation of air pollution, as well as its impacts on park resources.

Since the late 1970s, the NPS Air Resources Division has managed a comprehensive air quality program, emphasizing the collection of credible air quality information to support scientifically sound resource management decisions in parks. A key component of this effort is known as Park Vital Signs Monitoring, which is the organization of park units into monitoring networks to conduct long-term monitoring for key indicators of change, or "vital signs." In general, air quality monitoring in parks is done in conjunction with national networks for ozone, atmospheric wet and dry deposition, and visibility. This cooperative approach has been successful in producing high quality, defensible data that is spatially and temporally comparable, and provides a broad context for an individual park's air quality information. It is strongly recommended that resource managers considering air quality monitoring adopt this cooperative approach, because partnerships with national monitoring networks use limited funding more effectively and provide a more complete database on which to base air quality management decisions. In addition, monitoring and research activities by agency and university scientists should be encouraged to gain a better understanding of ecosystems and how they might be affected by air pollution.

1.2 OZONE AND ITS EFFECTS

Ground-level ozone, produced by the reaction of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight, is one of the most widespread pollutants affecting vegetation and public health in the U.S. Although ozone is principally viewed as an urban problem, ozone and its precursor emissions can travel long distances, resulting in elevated ozone levels in national parks. Combustion processes from power plants, automobiles, and industries are the main anthropogenic emitters of oxides of nitrogen. Vehicles, industries, and natural vegetation emit VOCs.

Exposure to ozone affects human health, causing acute respiratory problems, aggravation of asthma, temporary decreases in lung capacity in some adults, inflammation of lung tissue, and impairment of the body's immune system.

Ozone also affects vegetation in national parks. Research shows that some plants are more sensitive to ozone than humans, and effects to plants occur well below the EPA air quality standard. Ozone causes considerable damage to vegetation throughout the world, including agricultural crops and native plants in natural ecosystems. Ozone effects on natural vegetation have been documented throughout the U.S., particularly in many areas of the East and in California. A relatively small number of national parks have been surveyed for ozone injury; injury has been documented in Great Smoky Mountains, Shenandoah, Lassen Volcanic, Sequoia/Kings Canyon, and Yosemite National Parks. Ozone sensitive plant species occur at nearly all the parks in the Vital Signs Monitoring Program and it is likely that ozone injury is far more widespread than previously documented.

Ozone enters plants through leaf stomata and oxidizes plant tissue, causing changes in biochemical and physiological processes. Both visible foliar injury (e.g., stipple and chlorosis) and growth effects (e.g., premature leaf loss, reduced photosynthesis, and reduced leaf, root, and total dry weights) can occur in sensitive plant species. Long-term exposures can result in shifts in species composition, with ozone tolerant species replacing intolerant species.

In a natural ecosystem, many factors can ameliorate or magnify the extent of ozone injury at various times and places including soil moisture, presence of other air pollutants, insects or diseases, and other environmental stresses. NPS is currently conducting a risk assessment for parks, based on the concept that foliar ozone injury on plants is the result of the interaction of the plant, ambient ozone, and the environment. That is, the risk for foliar injury is high if three factors are present: species of plants that are genetically predisposed to ozone injury, concentrations of ambient ozone that exceed a threshold required for injury, and environmental conditions that foster gas exchange and the uptake of ozone by the plant. The risk assessment, which is expected to be completed in summer 2004, will be useful to resource managers in deciding whether to conduct future ozone monitoring or foliar injury assessments. The risk assessment will be available at *http://www2.nature.nps.gov/air/*.

1.3 MEASURABLE OBJECTIVES

Ground-level ozone is regulated under the Clean Air Act, the comprehensive federal law that regulates air emissions in the United States. Information about the Clean Air Act can be found at *http://www.epa/gov/epahome/laws.htm*. Among other things, the Clean Air Act requires the U.S. EPA to set standards for "criteria pollutants" – six commonly occurring air pollutants, one of which is ground-level ozone. These standards, known as the National Ambient Air Quality Standards (NAAQS), define the national targets for acceptable concentrations of each of the criteria pollutants. For each pollutant, EPA has developed two NAAQS standards:

- The "primary standard," which is intended to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly.
- The "secondary standard," which is intended to prevent damage to the environment and property, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

The NAAQS primary standard for ozone is exceeded when the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations, measured at each monitor within an area over each year, exceeds 0.08 parts per million (ppm), or equals or exceeds 85 parts per billion (ppb). The secondary standard defined by the EPA is the same as the primary standard.

To quantify ozone exposure to plants, scientists use various indices other than the primary and secondary standards. These indices, the SUM06 and the W126 in conjunction with the N100, are believed to be biologically relevant, as they take into account both peak ozone concentrations and cumulative exposure to ozone. Hourly ozone concentrations are needed to calculate these indices.

- SUM06 – A cumulative index that is calculated as the maximum running 90-day sum of the 0800-2000 hourly average ozone concentrations equal to or greater than 0.06 ppm. Several thresholds have been developed for SUM06:

Natural ecosystems	8 - 12 ppm-hr	(foliar injury)
Tree seedlings	10 - 16 ppm-hr	(1%-2% reduction in growth)
Crops	15 - 20 ppm-hr	(10% reduction in 25%-35% of crops)

- W126 – A cumulative index that is calculated as the maximum running 90-day sum of the 0800-2000 weighted hourly ozone concentrations, where a sigmoidal weighting function is used to give increasing significance (weights between 0 and 1) to concentrations of ozone greater than 0.04 ppm, and no weight to concentrations below 0.04 ppm.

- N100 – The number of hours over 100 ppb. The N100 index is often considered along with the W126 in assessing the possible impact of the exposure. Several thresholds have been developed for W126 and N100:

	W126	N100
Highly Sensitive Species	5.9 ppm-hr	6
Moderately Sensitive Species	23.8 ppm-hr	51
Low Sensitivity	66.6 ppm-hr	135

Over 40 parks currently have on-site ozone analyzers that provide hourly data. Trend analysis indicates that ozone is increasing in many areas. For parks without on-site monitoring, the NPS Air Atlas provides estimates based on spatial interpolations. Air Atlas (*http://www2.nature.nps.gov/air/maps/AirAtlas/index.htm*), is a geographic information system that looks at spatially interpolated air pollutant data from major national monitoring networks in which NPS participates. Estimates indicate that parks in certain areas of the country have SUM06 and W126 values sufficient to induce foliar injury.

In many areas of the U.S., ozone concentrations exceed the National Ambient Air Quality Standard. Over 100 park units are in these ozone nonattainment areas (see Figure 1-1). NPS has initiated pollution advisories in several parks warning visitors of potentially harmful levels of ozone.

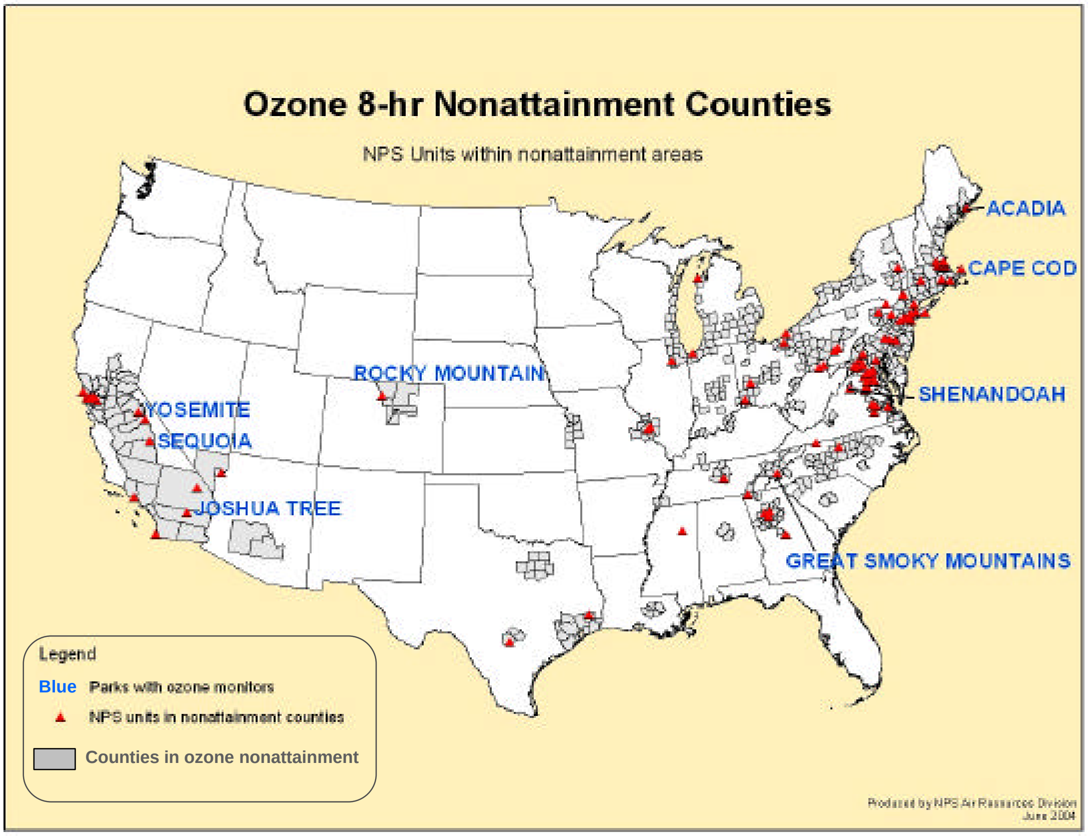

Figure 1-1. Nonattainment Areas in the United States, including NPS areas (areas where ozone concentrations exceed the NAAQS for ozone).

It is important to note that year-to-year changes in ambient ozone are influenced by meteorological conditions, population growth, and changes in emission levels of ozone precursors (i.e., VOCs and NO_X) resulting from ongoing control measures.

1.4 OZONE MONITORING AND RESOURCE MANAGEMENT OBJECTIVES

Resource managers may want to initiate on-site ozone monitoring to assess risks to human health and vegetation within their park unit. Managers should first consider whether representative monitoring data are available. Maps available on the NPS Air Atlas and EPA AIRNow (*http://www.epa.gov/airnow*) Web sites will help identify existing monitors. EPA, state, and local agencies operate over 2,000 continuous ozone analyzers nationwide to gauge compliance with the national standards for ozone, but they are concentrated in urban areas and are unlikely to represent conditions in parks. Currently, Ozone monitoring is conducted in over 40 national parks using continuous ozone analyzers, portable continuous ozone analyzers, and/or passive ozone samplers. The majority of parks, however, have no on-site or nearby monitoring; Air Atlas estimates, based on more distant monitors, may or may not be representative depending on geography, meteorology, and topography. A single monitor in a park may not be representative of the entire park if the park is large or has significant elevation changes. The NPS Air Resources Division (ARD) can provide guidance on determining representativeness.

If estimates from Air Atlas indicate that ozone is sufficient to affect human health or vegetation, resource managers may want on-site measurements to verify or refine the estimates. Monitoring may also be warranted if the risk for ozone injury to vegetation is high in the park, or if trend analyses indicate that ozone is increasing in the region. If future vegetation surveys are planned, on-site monitoring will provide data for calculating exposure indices that may be correlated to observed injury.

Because several options exist for monitoring ozone, determination of the sampling design, including selection of analyzing equipment, depends on the technical needs of a monitoring program and available resources. The NPS ARD has developed information and guidance to assist resource managers in characterizing current air quality conditions and identifying sensitive resources. Resource managers are encouraged to contact ARD for technical guidance and assistance in developing their plans.

The primary options available for monitoring ozone levels are briefly described below:

Continuous ozone monitoring is generally performed year-round on a long-term basis. It is also generally the option used if regulatory compliance is required. The method employs a continuous ozone analyzer that is configured as a reference or equivalent method specified by the EPA in Appendix D of 40 CFR Part 50. Continuous method monitoring provides hourly data, which is needed to determine NAAQS compliance and to calculate ozone exposure indices. A temperature controlled shelter, AC electrical power, and a telephone are required. The operational protocols are strictly defined so that the data accuracy and precision of the measurements can be clearly documented. An on-site operator will need to spend 4-6 hours per week servicing and maintaining the instrumentation. Independent calibration and maintenance of the systems must be done at least twice a year. This is the most expensive method, but can provide the highest quality, traceable data.

Portable continuous ozone monitoring is generally intended for short-term, seasonal use at locations where regulatory compliance is not required or is not practical. This method uses a continuous ozone analyzer (a miniaturized version of a traditional photometric ozone analyzer), and is designed for low power operation. The instrumentation can be solar and battery powered. A portable station does not currently meet EPA criteria as a certified method, but it provides hourly data that may be used as an indicator of NAAQS compliance and can provide vegetation exposure indices. The operator must spend 1-2 hours per week servicing and maintaining the instrumentation. This method is less costly than continuous monitoring and can provide a valuable data set for generally understanding the magnitude and dynamics of local ozone concentrations.

Integrated passive ozone monitoring can provide basic information on ozone exposures, provide information to help determine how continuous monitors can be used to fill data gaps, and provide information on where best to locate continuous monitors. This method is intended for short-term, seasonal use at locations where regulatory compliance is not required or is not practical. Passive samplers have no moving parts and do not require power to operate. The devices are similar to filter samplers in that individual samplers are analyzed in a laboratory to provide the integrated (average) ozone concentration over the sampling period (usually one week). The operator is required to spend 1/2 to 1 hour each week servicing the instrumentation. Passive samplers do not meet EPA criteria as a certified method, but they are the least expensive of the monitoring options.

Table 1-1 summarizes the variables and requirements for the monitoring options discussed above, and is intended to help air quality resource managers decide which monitoring option is best suited for their needs. More detail on each ozone monitoring method is contained in the following sections, and additional information can be obtained from the NPS ARD.

Table 1-1

Ozone Monitoring Option Considerations

Method	Data	NAAQS Compliance	Vegetation Exposure Indices	Siting Criteria	Utilities Required	Shelter Required	Operator Weekly Effort[2]	Typical Initial Cost[3,4]	Typical Annual Cost[5]	Lease Option
Continuous	Hourly	Yes	Yes	Rigid	AC / Telephone	Yes[1]	4-6 hours	$70,800	$21,000	Maybe
Portable Continuous	Hourly	No	Yes	Flexible	AC or Solar / Wireless Communications	No	1-2 hours	$21,000	$9,000	Maybe
Integrated Passive	Weekly Averages	No	No	Flexible	No	No	1/2 - 1 hour	$1,100	$1,500	Equipment Loan

[1] Temperature-controlled shelter.
[2] Excluding travel time to/from monitoring site.
[3] Including capital costs and installation.
[4] Lease options for short-term commitment may be available.
[5] Excluding site operator labor costs.

Monitoring may not be necessary in an area if there are other monitors operating nearby, and especially if measured concentrations are well below the EPA standards or if the risk for ozone injury is low. In this case, the spatially interpolated air quality inventory provided in Air Atlas may be deemed sufficient. Other monitoring options may be to partner with state or local air quality agencies, lease instrumentation, or monitor with other methods that may have specific uses (e.g., ozonesondes for vertical profiles, open-path optical methods, satellite determinations of ozone or other pollutants).

Ideally the type and number of monitoring sites within a park unit are determined by resource management needs, monitoring objectives, the diversity of air pollution emissions, meteorology, topography, and the degree of spatial resolution required of an area. The greater the diversity in these factors, the greater the number of monitoring sites that will be required to adequately characterize air quality levels. Realistically, however, this decision will usually be determined by budgetary constraints.

2.0 CONTINUOUS MONITORING

2.1 SAMPLING DESIGN

Ultraviolet (UV)-photometric ozone analyzers typically used in continuous monitoring, are capable of data output with time resolution on the order of seconds, but measurements are usually reported as hourly averages. Instrument collocation (replication) generally is not required for continuous ozone analyzers. If an objective is to comply with NAAQS, the data must pass EPA's Air Quality System (AQS) requirements. Hourly data are also required for use with vegetative exposure indices such as SUM06, W126, and N100.

Continuous ozone monitoring stations generally operate year-round, but may operate only during the ozone season, depending on the goals and resources of the sampling program. Since ozone levels decrease significantly in colder months in many areas, the EPA has designated ozone seasons for each state. These designations can be found in Appendix D of 40 CFR Part 58, or on the Internet at *http://www.epa.gov/oar/oaqps/greenbk/o3season.html*. Generally the ozone season is May through September.

Monitoring equipment will need to operate unattended for prolonged periods. Equipment required for continuous ozone monitoring includes an ozone analyzer meeting the reference or equivalent method specified by EPA in Appendix D of 40 CFR Part 50. EPA requires reference or equivalent methods to help assure that air quality measurements are accurate. The EPA maintains a list of designated reference and equivalent methods at *http://www.epa.gov/ttn/amtic*. Other required equipment includes a temperature controlled, walk-in shelter, a data acquisition device, calibration system, miscellaneous support equipment, and optional meteorological sensors (air temperature, relative humidity, wind speed, wind direction, solar radiation, and precipitation).

Standard security measures such as enclosures and fences will help safeguard the equipment and prevent interference with its operation. The continuous method of ozone monitoring also requires a walk-in shelter to protect the analyzer from precipitation and adverse weather conditions, maintain operating temperature within the analyzer's temperature range requirements, and provide security and electrical power. A telephone line is also required to transmit data from the on-site datalogger to a data collection facility. Figure 2-1 presents a typical instrument configuration for continuous monitoring. Figure 2-2 is a typical shelter with a meteorology tower.

The site should have reasonable access so that travel time by the operator is not excessive, and yet be unintrusive to the visitor and secure enough that analyzers are not disrupted. The site must be representative of the air mass to be sampled, away from sources of pollution, roads, parking lots, and combustion sources. It must be in an opening approximately 20 meters from trees and buildings, and have a probe height of 3-15 meters above ground. In order to determine NAAQS compliance, the continuous method has rigid siting criteria. More detailed guidance on siting considerations that meet EPA standards can be found in the Guideline on Ozone Monitoring Site Selection (*http://www.epa.gov/ttn/amtic/cpreldoc.html*).

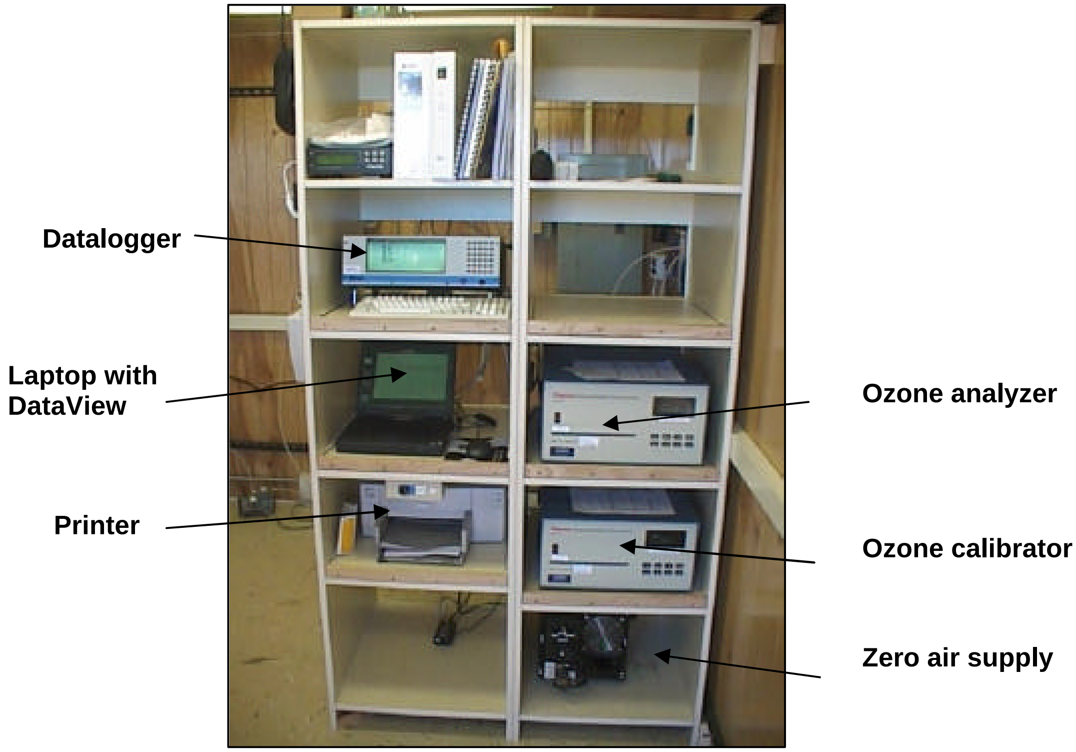

Figure 2-1. Typical Instrument Configuration for Continuous Ozone Monitoring.

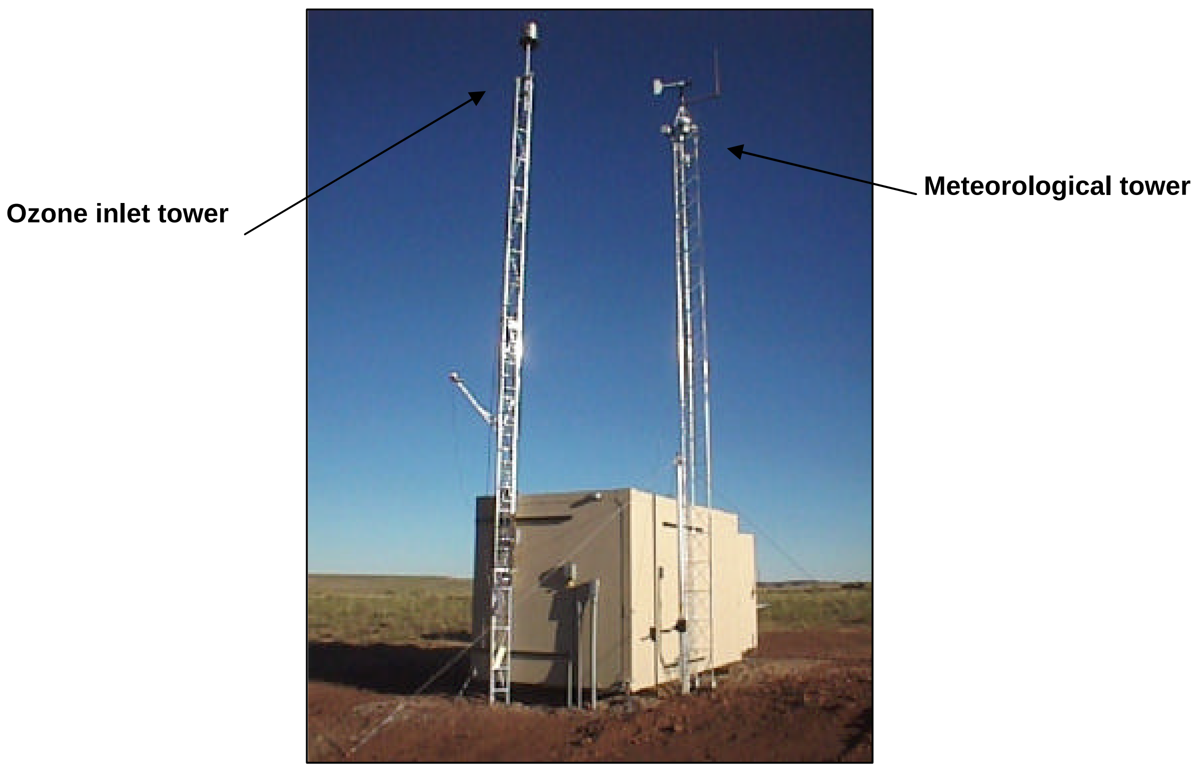

Figure 2-2. Typical Shelter and Meteorology Tower for Continuous Ozone Monitoring.

2.2 FIELD METHODS

Routine operations during a field season include instrument calibration and maintenance. Instrument calibrations are required to ensure the accuracy and precision of the instruments. Calibrations should follow protocols as established by EPA/600/4-77/027a *Quality Assurance Handbook for Air Pollution Measurement System: Volume II*, and Appendix B of 40 CFR 58 *Quality Assurance Requirements for Prevention of Significant Deterioration (PSD) Air Monitoring*. Automated nightly calibration checks of the instrument zero and upscale ozone value are recommended. A weekly visit by the site operator includes preventive maintenance and a manual check of instrument performance and calibration. Full system calibrations by an independent contractor, including a comparison to a traceable transfer or primary standard, are performed no less than every six months. All measurement devices and calibration standards should be traceable to the National Institute of Standards and Technology (NIST).

Stations equipped with continuous ozone monitors should output the data to a data acquisition system that compiles and averages the data. Data collection can be performed remotely (hourly or daily) by telephone or satellite modem. Daily data checks can be performed by either automated or manual review of data. Site visit checklists should be used by the site operator for weekly station check procedures.

2.3 DATA HANDLING, ANALYSIS, AND REPORTING

A database system should be used to collect, manage, validate, report, and archive hourly network data, related site information data, validation data, diagnostic data, and parameter data. A viable option may be inclusion in the database system maintained by the NPS ARD.

Data validation consistent with the NPS ARD network standards ensures timely validation of data using procedures that meet EPA standards. Three levels of data validation performed for the NPS ARD network are illustrated in Figure 2-3. Only Final validation level data meet all NPS and EPA validation requirements and are acceptable for submission to the NPS-validated data archives and the EPA AQS national database. More detailed information regarding NPS ARD data validation procedures can be found in Standard Operating Procedure 3450, *Ambient Air Quality and Meteorological Monitoring Data Validation* and its associated technical instructions.

A variety of reporting options may be used to provide the status and trends of ozone conditions. Reports should present monitoring objectives, actual data collected, quality assurance/quality control (QA/QC) methods used, statistical summaries, and interpretation analyses.

Example data reporting and submittal options are:

- Monthly/annual reports including:
  - Site attainment status for year based on primary and secondary NAAQS.
  - Scientifically instructive analysis such as monthly, diurnal, and day-of-week summaries and timelines.
  - Calculation of risk assessment indices for potential effects on vegetation.
  - Site metadata.
  - Quality assurance records.

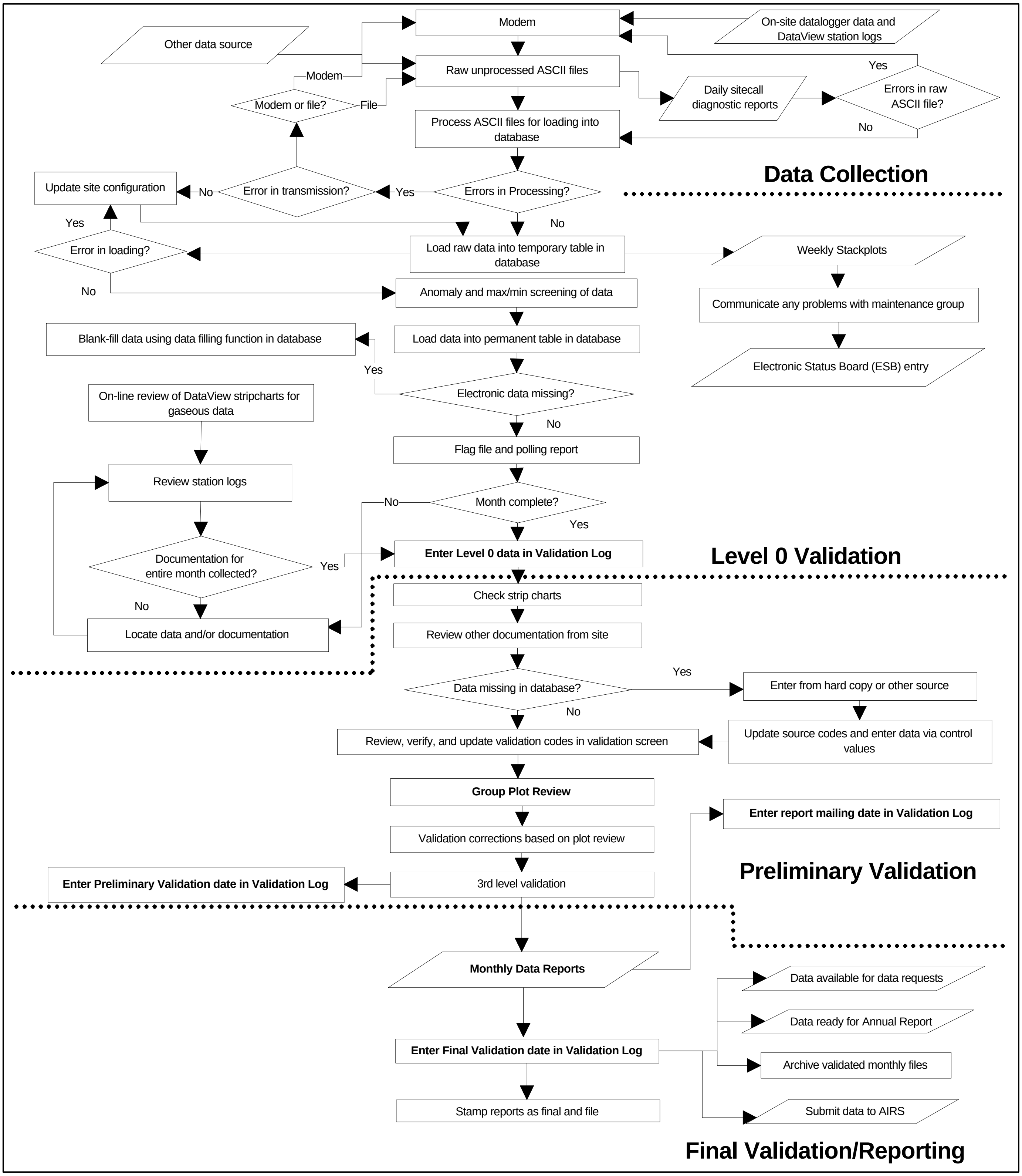

Figure 2-3. NPS Gaseous Pollutant Monitoring Program Network Data Collection, Validation, and Reporting Flow Diagram.

- Monthly/quarterly submittal of final validated regulatory data to the EPA's AQS database. These data include hourly average ambient air quality and meteorological data, precision data from ozone analyzer precision checks, and accuracy data from audit reports on ozone analyzers.

Final data sets should also be archived with all supporting documentation, including documentation of data files, data management procedures, and quality assurance data. Multiple copies of data sets should be stored, and care should be taken that all copies are updated simultaneously when additional material is added.

2.4 PERSONNEL REQUIREMENTS AND TRAINING

The primary purpose of routine site operator maintenance is to assure quality data capture and minimize data loss by performing weekly operational checks and system integrity checks, including verification that the ozone analyzer if functioning properly. The operator must thoroughly document the results of each weekly site visit with a station log. The largest variable in personnel requirements is the amount of time needed to troubleshoot the system in the event of system failure. Generally, 4-6 hours per week should be expected from the site operator to perform routine maintenance on a year-round basis, excluding time traveling to and from the monitoring site.

A network support contractor is generally used to provide higher level field operations and data management services. These services include equipment installations, periodic maintenance and calibrations, emergency service, site operator technical support, and data collection, validation, reporting, and archive.

If malfunction of any monitoring component occurs, or if any of the readings do not make sense, a contractor field specialist should be available to assist with troubleshooting procedures. The operator may be asked by the field specialist to perform certain mechanical, electrical, electronic, or datalogger program maintenance or equipment replacements. If the site operator cannot resolve the issue, emergency repair by the field specialist may be required.

The site operator should be fully trained on all required duties. Site operator training should be conducted by qualified field specialists upon initial installation of an air quality station, during twice-annual maintenance visits, and upon installation of new equipment. General qualifications for the site operator and contractor field personnel will include basic computer skills, simple electronic, and mechanical skills. Education and training in a scientific or technical field is beneficial, but not required.

The NPS ARD has air quality scientists that manage the national monitoring programs and analyze and interpret the collected data. Individual parks may also want to analyze and apply collected data to address park-specific issues. The roles and responsibilities of park scientists will vary with the specific applications. General requirements for an air quality scientist will include formal education and training in a related scientific or technical discipline, the ability to manage and interpret scientific data, and to analyze and apply the data to address air quality regulations and resource-related issues.

2.5 OPERATIONAL COSTS

Continuous ozone monitoring stations generally operate year-round and the site operator is required to perform weekly site visits. Comprehensive system maintenance and calibrations are performed by the network support contractor no less than twice annually. Approximate costs for this method are provided in Table 2-1. Note that cost will vary depending on specific site circumstances. The cost estimates listed in Table 2-1 should be used for planning purposes only. Instrumentation may also be leased (subject to availability); however, lease costs will generally exceed the purchase price for monitoring programs that last more than ten months.

Table 2-1

Monitoring Costs
Continuous Ozone Monitoring Method
Year-Round Operation

		Costs
Initial/Start-up		
Continuous ozone system components		$18,850**
Support system components	• Datalogger	$7,020
	• DataView and computer	$3,230
	• Climate-controlled shelter	$15,200
	• Utilities (power/phone/access)	$3,000
Meteorological system components		$6,800
Installation, site preparation, operator training	• Ozone	$23,500
	• Meteorology	$4,000
	Initial/Start-up Total Costs:	**$70,800* - $81,600**
Operation cost/year	• Ozone	$21,000
	• Meteorology	$9,000
	Annual Costs Total:	**21,000* - $30,000**
First year costs (start-up plus operating costs): $91,800 - $111,600		
Subsequent year costs: $30,000		

*The lower cost does not include meteorological monitoring. However, it is recommended that sites monitor meteorology to assist with validation and interpretation of ozone data.

** Lease options may be available for short-term monitoring applications. Contact the NPS ARD for further information.

3.0 PORTABLE CONTINUOUS MONITORING

3.1 SAMPLING DESIGN

Portable UV-photometric ozone analyzers are capable of data output with time resolution on the order of seconds, but measurements are usually reported as hourly averages. Portable continuous monitoring cannot be used to comply with NAAQS, but the data may be used to *indicate* compliance levels. The hourly data can be used to calculate vegetative exposure indices such as SUM06, W126, and N100. A fact sheet on portable monitors is available at *http://www2.nature.nps.gov/air/studies/portO3.htm*.

Portable continuous ozone monitoring stations generally operate during the ozone season of May through September. Since ozone levels decrease significantly in colder months in many areas, the EPA has designated ozone seasons for each state, which can be found in Appendix D of 40 CFR Part 58, or on the Internet at *http://www.epa.gov/oar/oaqps/greenbk/o3season.html*.

Monitoring equipment will need to operate unattended for prolonged periods. System components include a low-power UV photometric ozone analyzer, data acquisition device, mounting system, solar/battery power system, instrument enclosure, and meteorological sensors (air temperature, relative humidity, wind speed and direction, solar radiation, and precipitation). Options to the system include a filter pack sampling system, a second ozone analyzer to assess precision, and communications options (telephone, cellular telephone, telemetry satellite, or memory module). An example of a portable continuous monitoring station is shown in Figure 3-1. This method requires no special facility, power, or equipment needs.

The site should have reasonable access so that travel time by the operator is not excessive, and yet be unintrusive to the visitor and secure enough that analyzers are not disrupted. The site must be representative of the air mass to be sampled, away from sources of pollution, roads, parking lots, and combustion sources. It must be in an opening approximately 20 meters or greater away from trees and buildings, and have a probe height of greater than 2 meters above ground.

Figure 3-1. Typical Portable Continuous Ozone Monitoring Station.

3.2 FIELD METHODS

Portable analyzer calibration is similar to the calibration of an EPA reference monitor, but this usually occurs only prior to and after a monitoring season because calibration equipment and a sufficient power supply are not available on site. Daily zeros are automatically performed on the analyzer to assess its operational status. The site operator is required to make weekly visits to ensure that the system continues to be operational, and to occasionally change the ozone inlet filter.

Ozone concentrations are monitored and recorded continuously. Data collection can be performed remotely (hourly or daily) by telephone or satellite communication. Daily data checks can be performed by either automated or manual review of data. Details of a site visit should be recorded on a log sheet.

3.3 DATA HANDLING, ANALYSIS, AND REPORTING

A database system should be used to collect, manage, validate, report, and archive hourly network data, related site information data, validation data, diagnostic data, and parameter data. A viable option may be inclusion in a database system maintained by the NPS ARD.

Data validation consistent with the NPS ARD network standards ensures timely validation of data. Three levels of data validation performed for the NPS ARD network are illustrated in Figure 2-3. More detailed information regarding NPS ARD data validation procedures can be found in Standard Operating Procedure 3450, *Ambient Air Quality and Meteorological Monitoring Data Validation* and its associated technical instructions.

A variety of reporting options may be used to provide the status and trends of ozone conditions. Reports should present monitoring objectives, actual data collected, quality assurance/quality control (QA/QC) methods used, statistical summaries, and interpretation analyses.

Final data sets should also be archived with all supporting documentation, including documentation of data files, data management procedures, and quality assurance data. Multiple copies of data sets should be stored, and care should be taken that all copies are updated simultaneously when additional material is added.

3.4 PERSONNEL REQUIREMENTS AND TRAINING

The primary purpose of routine site operator maintenance is to assure quality data capture and minimize data loss by performing weekly operational checks and system integrity checks, including verification that the ozone analyzer if functioning properly. The operator must thoroughly document the results of each weekly site visit with a station log. The largest variable in personnel requirements is the amount of time needed to troubleshoot the system in the event of system failure. Generally, 1-2 hours per week should be expected from the site operator to perform routine maintenance on a summer-only basis, excluding time traveling to and from the monitoring site. A network support contractor will generally provide higher level field operations and data management services. These services include system installation and takedown, calibrations, site operator technical support, and data management.

If malfunction of any monitoring component occurs, or if any of the readings do not make sense, a contractor field specialist should be available to assist with troubleshooting procedures. The operator may be asked by the field specialist to perform certain mechanical, electrical, or datalogger program maintenance, and may be required to make equipment replacements.

The site operator should be fully trained on all required duties. Site operator training should be conducted by qualified field specialists upon initial installation of an air quality station. General qualifications for the site operator and contractor field personnel will include basic computer skills, electronic, and mechanical skills. Education and training in a scientific or technical field is beneficial.

The NPS ARD has air quality scientists that manage the national monitoring programs and analyze and interpret the collected data. Individual parks may also want to analyze and apply collected data to address park-specific issues. The roles and responsibilities of park scientists will vary with the specific applications. General requirements for an air quality scientist will include formal education and training in a related scientific or technical discipline, the ability to manage and interpret scientific data, and to analyze and apply the data to address air quality regulations and resource-related issues.

3.5 OPERATIONAL COSTS

Portable ozone monitoring may be conducted year-round but is usually only operated during the ozone season (typically May through September). The system is self-contained and is able to run reliably with minimum operator support. The site operator is required to service the site and equipment once per week.

Approximate costs for the portable continuous ozone monitoring method are provided in Table 3-1. Note that each installation is unique and cost will vary depending on specific site circumstances. The cost estimates listed in Table 3-1 should be used for planning purposes only. Instrumentation may also be leased (subject to availability).

Table 3-1

Monitoring Costs
Portable Continuous Ozone Monitoring Method
Five Month Season-Only Operation

		Costs
Initial/Start-up Standard Configuration	Includes the following components: • Low-power ozone analyzer • Tripod tower • Campbell datalogger • Instrument box • Automated zero check system • Inlet with Teflon filter • Wind speed and direction • Relative humidity • Solar radiation • Ambient temperature • Rainfall • Cell phone • Solar cells, battery pack – DC	$17,000**
Optional Components	• CASTNet-style Filter-pack (SO2, NO3, SO4, HNO3) • Satellite modem • Storage module • Near real-time Web data presentation • Hard-line phone • Radio phone extended • AC line power	costs vary
Installation, site preparation, operator training		$4,000
	Initial/Start-up Total Costs:	**$21,000***
Operation cost/ 5-month ozone season		$9,000
	Annual Costs Total:	**$9,000***
First year costs (start-up plus operating costs): $30,000* **Subsequent year costs: $9,000***		

*This cost does not include optional components.
** Lease options may be available. Contact the NPS ARD for further information.

4.0 INTEGRATED PASSIVE MONITORING

4.1 SAMPLING DESIGN

The exposure period for each passive sampler is normally one week, but 2-week, 1-day, and 8-hour sample periods are also possible. Sampling is performed with nitrite-coated filters that are exposed to air; ozone diffuses through the sample housing and reacts with the nitrite to form nitrate. Laboratory analysis of the filter by ion chromatography yields a nitrite mass that can be related to an ozone concentration. The document, "Study Design for Ozone Passive Sampling," provides additional information on passive samplers and is available at *http://www2.nature.nps.gov/air/studies/passives.htm*. In particular, the document discusses sampling design and the numbers of samplers to be used in parks with different numbers of sites.

Integrated passive ozone monitoring stations generally operate during the summer or growing season. Since ozone levels decrease significantly in colder months in many areas, only warmer months are of interest.

Monitoring equipment will need to operate unattended for prolonged periods. The NPS ARD uses the Ogawa passive ozone sampler (*http://ogawausa.com/passive.htm*), which requires a mounting system (a PVC rainshield and cross-arm, and support tower) and incidental supplies. An example of a integrated passive monitoring station is shown in Figure 4-1. The integrated passive monitoring method requires no special facility, power, or equipment needs.

The site should have reasonable access so that travel time by the operator is not excessive, and yet be unintrusive to the visitor and secure enough that samplers are not disrupted. The site must be representative of the air mass to be sampled, away from sources of pollution, roads, parking lots, and combustion sources. Samplers are generally mounted approximately 2-3 meters above ground.

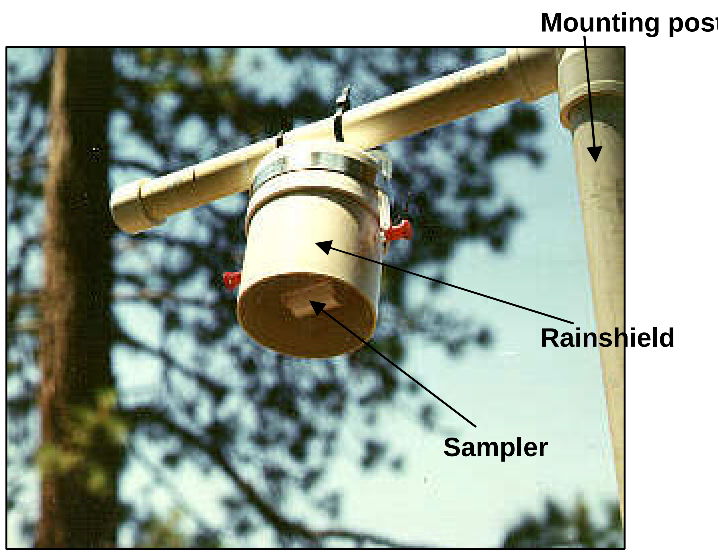

Figure 4-1. Typical Integrated Passive Ozone Monitoring Station
and Close-up of Sampler and Rainshield.

4.2 FIELD METHODS

Monitoring systems can be easily installed by the site operator. Routine operations during a field season include filter changing, shipping samples to an analysis lab, and filter documentation. A laboratory usually packages, labels, and ships loaded passive samplers before the scheduled sampler exposure. Each shipment should contain enough samplers for each exposure period during the month plus “blanks” that will not be exposed. Samplers not in use should be refrigerated or stored at room temperature in a location out of direct sunlight. The site operator unpacks and deploys the samplers according to a pre-determined schedule. The dates, times, sample numbers, and local observations are recorded on a log sheet as the official record. After exposure of each of the weekly samplers for that month, the site operator returns the samplers to the laboratory.

4.3 DATA HANDLING, ANALYSIS, AND REPORTING

A database developed for passive ozone samplers should include site information, lab results, blank and duplicate information, calculated ozone concentrations, and should allow for reports and queries of the database. Filter data received from the laboratory are loaded into the database and manually validated. Data export options and summary tables should also be available. A viable option may be inclusion in the database system maintained by NPS ARD.

After laboratory analysis is completed, the lab results, exposure times, and log sheets are collected together and actual ozone concentrations are calculated using lab data and blanks. Equations for the calculation of ozone concentrations are available in “Study Design for Ozone Passive Sampling” at *http://www2.nature.nps/gov/air/studies/passives.htm*. At the end of the season, all the ozone data are again reviewed and additional quality control checks are made, including checks for consistency, misidentifications, missing time and date codes, accurate periods of exposure, precision, and screening checks. Results can be compared to the nearest continuous ozone monitors, to national ozone standards, to other nearby parks, and to regional trends.

A variety of reporting options may be used to provide the status and trends of ozone conditions. Reports should present monitoring objectives, actual data collected, quality assurance/quality control (QA/QC) methods used, statistical summaries, and interpretation analyses.

Final data sets should also be archived with all supporting documentation, including documentation of data files, data management procedures, and quality assurance data. Multiple copies of data sets should be stored, and care should be taken that all copies are updated simultaneously when additional material is added.

4.4 PERSONNEL REQUIREMENTS AND TRAINING

An operator is required who can visit the monitoring site once a week and take an interest in the monitoring results, as well as maintain careful recordkeeping of station logs. Monitoring involves exposing the passive samplers for one week periods, retrieving the samplers, and mailing them to the analysis contractor with the log sheet. Generally, 1/2 to 1 hour per week should be expected from the site operator during the ozone season, excluding time traveling to and from the monitoring site.

The operator should follow the standard operating procedure. General qualifications for the site operator include basic mechanical and record-keeping skills. No special education and training are required, but scientific or technical training may be helpful in interpretation of the data.

The NPS ARD has air quality scientists that manage the national monitoring programs and analyze and interpret the collected data. Individual parks may also want to analyze and apply collected data to address park-specific issues. The roles and responsibilities of park scientists will vary with the specific applications. General requirements for an air quality scientist will include formal education and training in a related scientific or technical discipline, the ability to manage and interpret scientific data, and to analyze and apply the data to address air quality regulations and resource-related issues.

4.5 OPERATIONAL COSTS

Passive ozone monitoring is conducted only during the ozone season (typically May through September). A site operator is required to perform weekly site visits during the active monitoring period.

Approximate costs for the integrated passive ozone monitoring method are provided in Table 4-1. Note that each installation is unique and cost will vary depending on specific site circumstances, and cost estimates listed in Table 4-1 should be used for planning purposes only.

Table 4-1

Monitoring Costs
Integrated Passive Ozone Monitoring Method
Ozone Season-Only Operation

	Costs
Initial/Start-up	
System components (O_3 only)	$1,000*
Installation, site preparation, operator training	$100
Initial/Start-up Total Costs:	**$1,100**
Operation cost/year	$1,500
Annual Costs Total:	**$1,500**
First year costs (start-up plus operating costs): $2,600	
Subsequent year costs: $1,500	

* Equipment loan may be available. Contact the NPS ARD for further information.

5.0 REFERENCES

National Park Service

Air Quality in the National Parks, 2nd Ed.: *http://www2.nature.nps.gov/air/pubs/aqnps.htm*

NPS Air Atlas: *http://www2.nature.nps.gov/air/maps/AirAtlas/index.htm*

NPS Gaseous Pollutant Monitoring Network: *http://www2.nature.nps.gov/air/monitoring/network.htm*

NPS ARD Passive Ozone Monitoring: *http://www2.nature.nps.gov/air/studies/passives.htm*

NPS ARD Portable Ozone Monitoring: *http://www2.nature.nps.gov/air/studies/portO3.htm*

NPS Gaseous Pollutant Monitoring Program Standard Operating Procedures: *http://ard-aq-request-air-resource.com/project*

Ozone Sensitive Plant Species on National Park Service and U.S. Fish and Wildlife Service Lands: *http://www2.nature.nps.gov/air/Pubs/BaltFinalReport1.pdf*

Environmental Protection Agency

Code of Federal Regulations: *http://www.epa.gov/ttn/amtic*
40 CFR 50, Appendix D. July 1995.
40 CFR 58, Appendix B. July 1995.
40 CFR 58, Appendix D. July 1995.
40 CFR 58, Appendix E. July 1995.

EPA AIRNow: *http://www.epa.gov/airnow*

EPA Guideline for Ozone Monitoring Site Selection: *http://www.epa.gov/ttn/amtic/cpreldoc.html*

Quality Assurance Handbook for Air Pollution Measurement Systems: *http://www.epa.gov/ttnamti1/files/ambient/qaqc/qamanual.txt*

Volume I. A Field Guide to Environmental Quality Assurance (EPA/600/R-94/038a).
Volume II. Ambient Air Specific Methods (EPA/600/R-94/038b).
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Volume IV. Meteorological Measurements (EPA/600/R-94/038d).
Volume V. Manual for Precipitation Measurement Systems (EPA/600/R-94/038e)